Langley Research Center

LPR 1710.6

Effective Date: May 18, 2006

Expiration Date: May 18, 2011

ELECTRICAL SAFETY

National Aeronautics and Space Administration

TABLE OF CONTENTS

Responsible Office: Safety and Mission Assurance Office

PREFACE

P.1 PURPOSE

This Langley Research Center (LaRC) Procedural Requirements (LPR) sets forth minimum electrical safety requirements and standards within the framework of LaRC safety policies and constraints. It is for use by professionals routinely engaged in electrical work. It is not an instruction manual for untrained personnel nor is it a substitute for detailed procedures judged necessary for the safe conduct of a specific task by individuals and their supervisors.

These procedural requirements contain both guidance and requirements for the assurance of safe working environments for professionals routinely engaged in electrical work at LaRC.

P.2 APPLICABILITY

These procedural requirements apply to all persons performing work at LaRC, including civil servants, contractors, research associates, and others. Non-compliance with this LPR will result in appropriate disciplinary action that may include termination for a civil servant employee or exclusion from the Center for a contractor employee.

LaRC is a multi-building industrial complex, whereby electrical power is obtained from the local electrical utility and distributed to the various buildings and facilities via a Center-owned and operated power distribution system comprised of industrial substations, high-voltage cabling, and power distribution equipment. For the application of referenced codes, standards, and regulations in this document, the “service points” for buildings and facilities at LaRC are identified on Effort Code 300 Switching Diagrams, which are described in Paragraph 3.3.1. The power distribution system up to the “service point” is covered by ANSI/IEEE C2-NESC, and electrical installations beyond the “service point” are covered by the NFPA 70, “National Electrical Code (NEC)”. NFPA 70E is applicable for the same installations covered by the NEC.

P.3 AUTHORITY

Compliance with the latest editions of the following standards and codes is a requirement of this document. A brief explanation of the scope of coverage for each is provided.

a. NFPA 70, NEC: This code covers electrical installation requirements for electrical conductors and equipment installed beyond the “service point” within or on public and private buildings and other premises.

b. NFPA 70B, "Recommended Practice for Electrical Equipment Maintenance": This document covers maintenance of industrial-type electric systems and equipment, electrical testing, and methods for safe de-energization of equipment.

c. NFPA 70E, "Standard for Electrical Safety in the Workplace": This standard is a companion document to the NEC and covers electrical safety-related work practices for the same industries and installations covered by the NEC.

d. ANSI/IEEE C2-NESC, "National Electrical Safety Code": This code covers power and communication lines, equipment, and associated work practices used by both public and private electric supply and similar utilities. It also covers power distribution systems serving multi-building industrial complexes, which are under the control of qualified persons such as the LaRC power distribution system. Major coverage includes methods and installation and maintenance rules for: 1) Grounding, 2) Electric Supply Stations and Equipment, 3) Overhead Electric Supply Lines, 4) Underground Electric Supply Lines, and 5) Operation of Electric Supply Lines and Equipment.

e. OSHA, "Occupational Safety and Health Act": These standards represent federal law and cover conditions, practices, or operations to assure safe and healthful work places. Specific coverage is as follows:

(1) OSHA 29 CFR 1910.147 of Subpart J – Control of Hazardous Energy Sources (Lockout-Tagout): While not an electrical standard, with certain additions this rule can be used for electrical tagout as permitted under OSHA CFR 1910, Subpart S.

(2) OSHA 29 CFR 1910.269 of Subpart R – Power Generation, Transmission, and Distribution: This subpart covers operation and maintenance of equipment used for power generation, transmission, or distribution and under the control of an electric utility.

(3) OSHA 29 CFR 1910, Subpart S – Design Safety Standards and Safety-Related Work Practices: The first paragraph of this subpart covers design and installation requirements for utilization equipment. The remainder covers the procedures required to ensure optimum safety of employees when working around energized or potentially energized equipment.

(4) OSHA 29 CFR 1926, Subpart K – Electrical: This subpart covers electrical safety requirements for employees involved in construction activities.

(5) OSHA 29 CFR 1926.550 of Subpart N – Cranes and Derricks: This subpart covers safety requirements for use of cranes and lifting equipment, including use around exposed energized conductors.

(6) OSHA 29 CFR 1926, Subpart V – Power Transmission and Distribution: This subpart covers electrical safety requirements for employees involved in the construction of new electric transmission and distribution lines and equipment.

f. In addition, the recommendations of industrial consensus standards for electrical equipment design and manufacturing shall be followed to the greatest extent practicable when designing and installing electrical systems at LaRC. Some of these standards-making organizations and coverage are described below:

(1) National Electrical Manufacturer's Association (NEMA) - These standards cover electrical power equipment including standard ratings, performance, testing, manufacturing, and marking.

(2) Electronic Industries Association (EIA) - These standards cover electronic-type electrical equipment and components.

(3) The Insulated Power Cable Engineers Association (IPCEA) and Association of Edison Illuminating Companies (AEIC) - These standards cover insulated power, control, and communication cable.

(4) Institute of Electrical and Electronic Engineers, Inc. (IEEE) - These standards consist of technical reports, testing procedures generally used in electrical power generation, distribution, and utilization.

(5) American National Standards Institute (ANSI) - These standards are a cataloging of new and existing standards under a common file system. The ANSI standard often has dual cataloging designations.

(6) Instrumentation, Systems, and Automation (ISA) Society - These standards and recommendations cover the development and application of industrial instrumentation and process controls.

P.4 REFERENCES

a. NPR 8715.3, “NASA Safety Manual” – The central Agency document that defines the NASA Safety Program.

b. LAPD 1150.2, “Councils, Boards, Panels, Committees, Teams, and Groups” – Defines charter, membership and other responsibilities of boards, panels, committees, and teams at LaRC.

c. LAPD 1700.2, “Safety Assignments” – Defines the duties, functions, and responsibilities of Facility Safety Heads and Facility Coordinators at LaRC.

d. LPR 1710.10, “Safety Clearance Procedures for the Control of Hazardous Energy (Lockout/Tagout)” – Defines the requirements to ensure personnel and equipment safety by controlling hazardous energy sources.

e. LPR 1740.2, “Facility Safety Requirements” – Defines the minimum safety requirements for facilities under LaRC management.

f. LPR 1740.4, “Facility System Safety Analysis and Configuration Management” – Defines the requirements for the LaRC Safety and Configuration Management (CM) programs for the Center’s ground-based research facilities.

g. LPR 1740.6, “Personnel Safety Certification” – Defines the certification requirements for personnel who perform functions at LaRC that require unique occupational safety qualifications.

h. NASA Langley Form 60, "Confined Space Entry Permit."

i. NASA Langley Form 416, “LaRC Energized Electrical Work Permit”

j. NASA Langley Form 453, “NASA Langley Safety Operators Permit”

k. NASA Langley Form 495, “Safety Operation Clearance Procedure”

P.5 CANCELLATION

LPR 1710.6, dated October 3, 2004, is rescinded and should be destroyed.

Original signed on file

Lesa B. Roe
Director

DISTRIBUTION:
305/Safety and Facility Assurance Branch, Safety and Mission Assurance Office (25 copies)

1 WORK REQUIREMENTS

1.1 Implementation of the NEC

1.1.1 The NEC is revised and a new edition is issued on a 3-year cycle. The policy for implementation of the revised edition of the NEC for use at LaRC is:

1.1.1.1 The Chairperson, Electrical Systems Committee (ESC), will issue a memorandum establishing the date of implementation for all new editions of the NEC. (See LAPD 1150.2, "Councils, Boards, Panels, Committees, Teams and Groups.")

1.1.1.2 There is no general provision in the NEC requiring any NEC changes or updates to be retroactive. Therefore, the upgrade of an electrical system merely to meet the changed NEC is not required.

1.1.1.3 The revised NEC requirements shall immediately be implemented if the implementation will improve the safeguarding of personnel or will protect LaRC equipment. Such determinations will be made in consultation with the Office of the Chief Counsel, the Center Operations Directorate, and the Safety and Mission Assurance Office.

1.1.1.4 The requirements of the latest adopted version of the NEC shall be used for all new electrical work unless there are more stringent requirements imposed by LaRC policy.

1.1.1.5 If a facility is being constructed when the new NEC is adopted, the ESC will evaluate the new NEC requirements and determine if there are reasons to incorporate any changes into the construction contract. If so, the ESC will issue a memorandum to the appropriate line organizations requesting that these changes be incorporated into the contracts.

1.1.1.6 Electrical equipment, which is modified, shall be brought up to the requirements of the latest version of the NEC unless the modifications to the equipment do not significantly change the function or design of the system. Electrical wiring and equipment that is not included in the modification does not have to be updated.

1.2 Definitions

1.2.1 Buddy System: The practice of employing a second electrically qualified person to directly observe the electrical work of an electrically-qualified person working on or near unguarded electrical equipment energized at 50 volts or more.

1.2.2 Cardiopulmonary Resuscitation (CPR): A procedure designed to restore normal breathing after cardiac arrest that includes the clearance of air passages to the lungs and heart massage by the exertion of pressure on the chest.

1.2.3 De-energized: Free from any electrical connection to a source of potential difference and from electrical charge; not having a potential different from that of the earth. (NFPA 70E)

1.2.4 Electrically Safe Work Condition: Energized at less than 50 volts or de-energized, locked and tagged, tested to ensure the absence of voltage, and grounded if deemed necessary. (NFPA 70E)

1.2.5 Energized: Electrically connected to a source of potential difference.

1.2.6 Energized Electrical Work Permit: A management approved, written permit required by NFPA 70E to work on energized equipment that cannot be placed in an electrically safe work condition.

1.2.7 Exposed (as applied to energized parts): Capable of being inadvertently touched or approached nearer than a safe distance by a person, especially parts that are not suitably guarded, isolated, or insulated. (NFPA 70E)

1.2.8 Fail-Safe: The capability to go to a predetermined safe state (i.e. minimum energy or minimized hazard condition) in the event of a specific malfunction.

1.2.9 Field Verified (as applied to electrical configuration controlled drawings): Verification that the drawing accurately depicts the configuration of installed systems or equipment by visual comparison and by point-to-point wire checks prior to placing the system into service. Point-to-point wire checks require ringing out or talking down the wiring between points of termination and are usually done during installation.

1.2.10 Functionally Verified (as applied to electrical configuration controlled drawings): Verification that the drawing accurately depicts the configuration of a functional system or equipment by visual comparison.

1.2.11 Grounded: Connected to earth or to some conducting body that serves in place of the earth. (NFPA 70E)

1.2.12 Guarded: Covered, shielded, fenced, enclosed, or otherwise protected by means of suitable covers, casings, barriers, rails, screens, mats, or platforms to remove the likelihood of approach or contact by persons or objects to a point of danger. (NFPA 70E)

1.2.13 High Voltage: Voltage class designation for electric power systems and equipment operating above 600 volts.

1.2.14 Live Part: Energized conductive component. (NFPA 70E)

1.2.15 Lockout/Tagout (LOTO): The full procedure of determining what is required to make a system safe; the action of making the system safe; and the placing of locks, locking devices, and red tags to preclude changing from the safe condition.

1.2.16 Low Voltage: Voltage class designation for electric power systems and equipment operating at 600 volts or less.

1.2.17 Qualified Person: One who has been trained in and demonstrates adequate knowledge of the installation, construction, or operation of electrical equipment and has received safety training on the hazards involved. One who is undergoing on-the-job training and, who in the course of such training, has demonstrated an ability to perform duties safely at that level of training, and who under the direct supervision of a qualified person, is considered to be a qualified person for the performance of those duties.

1.2.18 Safety Operator (SO): Individual who has been qualified and certified to perform Red Tag Lockout/Tagout on electrical systems for which the Red Tag LOTO is requested and possesses a current NASA Langley Form 453, “NASA Langley Safety Operators Permit." LaRC SO’s are the only persons authorized to hang or remove red locks, red tags, and associated locking hardware.

1.2.19 Service Point: The point of connection between the facilities of the serving utility and the premises wiring. (NEC) Service points for the facilities at LaRC are identified on Effort Code (EC) 300 Switching Diagrams.

1.2.20 Unqualified Person. A person who is not qualified. (NFPA 70E)

1.2.21 Voltage (of a circuit): The greatest root-mean-square (rms) (effective) difference of electrical potential between any two conductors of the circuit concerned. (NFPA 70E)

1.3 General Requirements

1.3.1 Consider all electrical circuits and equipment energized until properly tested by a qualified worker and witnessed by a second qualified person.

1.3.2 Equipment operating at or above 50 volts shall be de-energized and have lockout/tagout performed prior to performing maintenance, service, and troubleshooting if there is a possibility that an employee may work on or near exposed energized parts in accordance with NFPA 70E, Art. 130.1. Energized parts that operate at less than 50 volts to ground need not be de-energized if there will be no increased exposure to electrical shock or other injuries resulting from direct or indirect electrical contact.

1.3.3 The buddy system, a second electrically qualified person directly observing the operation, is mandatory whenever electrical work (including measurements) is to be performed on exposed energized circuits of 50 volts (phase-to-phase) or higher.

1.3.4 Before commencing work on any mechanical equipment or systems which have electrical connections or contain explosive, combustible, or other dangerous gases or fluids, the equipment or systems shall be properly grounded and/or made safe in accordance with other LaRC safety regulations concerning these materials.

1.3.5 Disconnecting means shall be legibly marked to indicate its purpose, unless located and arranged so the purpose is evident. Labeling shall indicate the source of power for the disconnecting means.

1.3.6 Up-to-date circuit directories shall be provided on all panelboards to clearly identify the purpose or load of each circuit. Circuit identification shall be in sufficient detail to distinguish each circuit from all others.

1.3.7 Switchboards, panelboards, and motor control centers shall be clearly labeled to warn qualified persons of potential arc flash hazards when working on energized equipment. Labeling shall meet the requirements of the NEC.

1.3.8 Electrical wall outlets shall be labeled to indicate the source electrical panel number and circuit number.

1.3.9 Identification markings on building light and power distribution panels, circuits, and components shall not be relied on for establishing safe work conditions.

1.3.10 Ground wires or connections to frames or cases are not to be removed from any energized equipment.

1.3.11 Earth return shall not be used in the wiring of any power circuit.

1.3.12 Non-conductive fish tape shall be used when pulling wires through a conduit into energized equipment.

1.3.13 Commutating-type tools shall not be operated in close proximity to volatile materials.

1.3.14 Portable ladders shall have non-conductive side rails, if they are used where the employee or ladder could contact exposed live parts operating at 50 volts or more or where an electrical hazard exists. Nonconductive ladders shall meet the requirements of ANSI standards for ladders in NFPA 70E, Table 130.7(F). Metal ladders shall be marked with signs or decals reading **CAUTION - DO NOT USE NEAR ELECTRICAL EQUIPMENT**.

1.3.15 When possible, stand to the side away from the door/cover when operating (opening or closing) disconnect switches.

1.3.16 Only devices designed for voltage testing and rated for the nominal voltage of the circuit under test shall be used to make voltage checks. Test voltage indicators shall be verified immediately before and after use by application to an energized circuit or by using an appropriate test unit.

1.4 Specific Requirements

1.4.1 Live Work Requirements

1.4.1.1 Live parts to which an employee might be exposed shall be put into an electrically safe work condition and locked/tagged out before an employee works on or near them, unless the employer can demonstrate that de-energization introduces additional or increased hazards or is infeasible due to equipment design or operational limitations. (NFPA 70E, Art. 130.1)

1.4.1.2 Equipment normally energized above 600 volts shall always be considered energized unless protective grounds and/or other appropriate safety measures, in accordance with LPR 1710.10, “Safety Clearance Procedures for the Control of Hazardous Energy (Lockout/Tagout),” are confirmed to be in place.

1.4.1.3 If de-energizing equipment introduces additional or increased hazards or is infeasible due to equipment design or operational limitations, a detailed procedure shall be developed for the energized work and documented on NASA Langley Form 416, "Energized Electrical Work Permit." The detailed procedure may be a separate document referenced by the Energized Electrical Work Permit. Work authorized by the Energized Electrical Work Permit shall be performed only by electrically-qualified personnel.

1.4.1.4 No work (other than performing routine testing, troubleshooting, and voltage measurements) shall be performed on energized power circuits of 600 volts or less without a NASA Langley Form 416.

1.4.1.5 Removal of switchgear panels or panel door barriers from energized circuits above 600 volts for inspection, data gathering or infrared testing of the exposed energized bus shall not be performed without an NASA Langley Form 416.

1.4.1.6 Workers shall not work alone on equipment with exposed energized parts operating at 50 volts or higher.

1.4.2 Personal Protection Equipment (PPE)

1.4.2.1 Personal Protective Equipment (PPE) shall be used to mitigate the hazards of electrical shock and electrical burns from arc-flash when work is to be performed on energized equipment and personnel are within the approach boundaries for shock protection as defined in NFPA 70E, Art. 130.2, and within the flash protection boundary for arc flash as defined in NFPA 70E, Art. 130.3(A).

1.4.2.2 PPE shall be selected based on the requirements of NFPA 70E, Art 130, Table 130.7(c)(9)(a) defining hazard/risk category for electrical tasks and Table 130.7(c)(10) defining required PPE based on hazard/risk categories. (See Appendices A and B.)

1.4.2.3 Conductive articles of jewelry and clothing (such as watchbands, bracelets, rings, key chains, necklaces, metalized aprons, cloth with conductive thread, metal headgear, or **metal frame glasses**) shall not be worn without appropriate PPE where they present an electrical contact hazard with exposed live parts.

1.4.2.4 Rubber gloves alone shall not be relied upon for protection from energized circuits of more than 3500 volts to ground.

1.4.3 Storage of Protective Devices

1.4.3.1 Protective equipment shall be maintained in a safe, reliable condition. The protective equipment shall be visually inspected before each use. Specific requirements for periodic testing of electrical equipment are given in NFPA 70E, Art. 130.7(C)(8).

1.4.4 Hard Hat Area

1.4.4.1 Electrical substations with exposed bus are designated as “hard hat” areas. Personnel within the confines of these substations shall wear Class E, Type 1, or Type 2 hard hats.

1.4.5 Welding

1.4.5.1 Welding or burning shall not be permitted in the immediate vicinity of electrical equipment. This requirement shall not restrict the work associated with the splicing or termination of lead-sheathed cable. Any deviations to this paragraph shall have the concurrence of the Facility Coordinator and the Electrical Standard Practice Engineer.

1.4.6 Lockout/Tagout

1.4.6.1 The application of lockout/tagout devices shall be in accordance with LPR 1710.10, “Safety Clearance Procedures for the Control of Hazardous Energy (Lockout/Tagout)”.

1.4.7 Confined Space Entry

1.4.7.1 A LaRC approved NASA Langley Form 60, "Confined Space Entry Permit," shall be required before entry into confined spaces, such as manholes or vaults, in accordance with LPR 1740.2, “Facility Safety Requirements”.

1.4.8 Portable Equipment Grounding

1.4.8.1 The cases of all portable electrical motor-driven hand tools are to be grounded by use of standard three-prong plugs and receptacles and all other electrical equipment supplied with 50 volts or above are to have their cases or frames connected to ground, except:

(a) Devices operated solely from self-contained batteries

(b) Devices which have cases and all exposed parts protected by insulating material

(c) “Double insulated” tools

1.4.9 Temporary Wiring

1.4.9.1 Temporary electrical wiring shall not be run directly on ungrounded conductive surfaces but shall be supported by suitable wood or other insulating materials.

1.4.9.2 Temporary electrical wiring and portable electrical cords shall be kept out of water at all times unless the cable is approved by the NEC for that purpose.

1.4.10 Extension Cords

1.4.10.1 Extension cords usage shall abide by the restrictions for temporary wiring as delineated in Section 5.3 of this document.

1.4.10.2 Extension cords shall not be used for more than 90 consecutive days without LaRC Safety Manager Approval.

1.4.10.3 Where extension cords are utilized, they shall not be:

(a) Used as a substitute for the fixed wiring of a structure

(b) Routed through holes in walls, ceiling, or floors

(c) Run through doorways, windows, or similar openings

(d) Attached to building surfaces

(e) Concealed behind building walls, ceilings, or floors

1.4.10.4 Extension cords shall be Underwriter's Laboratory (UL) listed.

1.4.10.5 Extension cords shall have adequate current carrying capacity to handle the maximum current draw of the connected electrical device. Extension cords shall be sized in accordance with NFPA 70B, Table 19.5 based on cord length and load current.

1.4.10.6 High current equipment (i.e. Microwave ovens, space heaters, and coffee pots) shall be plugged directly into wall receptacles.

1.4.10.7 Extension cords shall be of the three-pronged grounded type, and suitable for the conditions of use and location.

1.4.10.8 A surge protector power strip is a special type of extension cord intended to protect computers and related equipment from damaging power fluctuations. Surge power strips shall not be used with electrical equipment other than computers and related equipment.

1.4.10.9 Extension cords used in outdoor or wet locations shall utilize integral or separate Ground Fault Circuit Interrupters (GFIC's) for shock protection.

1.5 Above 600 Volts (High Voltage)

1.5.1 Protective Grounding - General

1.5.1.1 Protective grounds are temporary grounding and short circuiting conductors, which are placed on de-energized electrical equipment for personnel protection. These grounds are a temporary protective measure and should not be confused with the fixed ground system required by NEC. Protective grounds are normally used to prevent accidental energizing of equipment and systems and shall be applied to any equipment when, in the opinion of the worker, the worker's supervisor, or the safety supervisor, the application is required. If protective grounds are determined to be necessary, they shall be applied before beginning work on systems or equipment, which may bring personnel into contact with parts, which are normally energized above 600 volts.

1.5.1.2 The Safety Operator shall be responsible for testing the system to ensure that no voltage is present prior to providing safety clearance. When grounds are determined to be necessary, it shall be the responsibility of the Safety Operator to ensure that adequate grounds are placed for the protection of the workers.

1.5.1.3 Before attaching protective grounds, the equipment or circuit to be protected shall be de-energized, tested to verify that the voltage is zero, and locked and tagged as required by LPR 1710.10. All conductors, static wires, circuit neutrals, and cable sheaths shall be connected in a manner which will ground all conductive portions of the circuit to a common point. The protective grounds shall not be removed until all workers are clear of the circuit or equipment. The ground end of the protective grounding cable shall always be connected first and disconnected last. Protective grounding cables shall not be less than 2/0 AWG copper or equivalent. Special requirements for some specific configurations are given below.

1.5.2 Protective Grounding - Overhead Lines and Pole Work

1.5.2.1 All protective grounding cables shall be connected to an approved ground point, which may be a grounded metal structure, a substation ground point,

an anchor rod, or a driven or screw-type ground rod. A multi-grounded common neutral of 2/0 AWG copper or equivalent is an acceptable ground for pole work. Pole guy wires are not acceptable ground points.

1.5.2.2 Circuit conductors shall be grounded by attaching the grounded cables to the conductors, progressing upward and outward from the work point. Personnel shall remain as far below the conductors as possible, keeping clear of the grounded cables and clamps. At the completion of work, grounding cables shall be removed in reverse order from installation, keeping clear of the cables and clamps until all conductors have been ungrounded.

1.5.3 Protective Grounding - Transformers

1.5.3.1 Before working on transformers, the following shall be performed:

(a) Open the transformer primary disconnect switch

(b) Remove the secondary fuses or open the secondary breaker

(c) Check the system to verify that the voltage is zero

(d) Install protective grounds

(e) Install insulated barriers or boards to isolate energized studs

1.5.3.2 Where connected transformers are in the zone between protective grounds, the primary side of the transformer shall be disconnected by either removing the line taps or opening the fuse cutouts. Where primary line work is to be performed on the transformer, the secondary wires shall also be disconnected or protective grounds applied. The secondary neutral, if established as grounded, may be considered as an adequate ground. On distribution transformers, the secondary neutral shall be considered an adequate ground for protective grounding, if the permanent ground is interconnected with the secondary neutral, the transformer case and a ground electrode.

1.5.4 Protective Grounding - Current and Potential Transformers

1.5.4.1 Before working on an instrument or other device in a current transformer secondary circuit, the transformer secondary circuit shall be shorted together or bridged in such a manner as to prevent opening the secondary circuit.

1.5.4.2 Current transformer cases and secondaries shall be grounded.

1.5.4.3 When more than one set of current transformer secondaries are electrically connected, a ground point shall be selected that provides grounding for the network.

1.5.4.4 When the primary circuit is energized, secondaries of current transformers shall not be opened.

1.5.4.5 The case and one wire on the low-voltage side of a potential transformer shall always be grounded before energizing the transformer.

1.5.5 Protective Grounding - Power Capacitors

1.5.5.1 A period of at least five minutes shall elapse after de-energizing power capacitor units or banks before protective grounds are installed. All capacitor units in the working area, and any other capacitor units adjacent to the working area that could be contacted, shall be short circuited and grounded.

1.5.5.2 All individual power capacitor tanks shall be grounded. In the case of capacitors installed in banks on insulated conductive mounting racks, the racks shall also be grounded before working on the bank.

1.5.6 Protective Grounding - Underground Cables

1.5.6.1 Protective grounding of conductors in underground cables cannot always be performed at the point of work. Protective grounds shall be attached at the nearest location where the conductors can be reached. Conductive sheathing or shielding tape shall have a protective ground applied on both sides of the work point.

1.5.7 Underground Utilities and Operations - General Requirements

1.5.7.1 A LaRC approved NASA Langley Form 60, "Confined Space Entry Permit," shall be required before entry into any manhole or vault as required in Paragraph 1.4.7.1 of this document. For specific requirements related to confined space entry, see LPR 1740.2.

1.5.7.2 Manhole cover hooks, cover lifters, or recessed handles shall be used for removing or replacing manhole covers.

1.5.7.3 Open manholes, hand holes, or vault gratings shall be protected by suitable barriers or guards and adequate lighting shall be provided during hours of darkness. In addition, safety cones and warning flags shall be used to direct vehicular and pedestrian traffic around such openings.

1.5.7.4 When practicable, manholes shall be entered or exited by means of a ladder.

1.5.7.5 When working in manholes, hand holes, or vaults, one person shall be stationed on the surface, to be readily available to those working below the surface.

1.5.7.6 Tools and materials shall be raised or lowered in manholes by means of a suitable bucket, toolbox, or rope.

1.5.7.7 Manhole covers and gratings shall be properly seated when replaced.

1.5.7.8 Approved lighting units shall be used when working underground, or below grade.

1.5.7.9 Air-driven tools used around energized cables shall be grounded.

1.5.7.10 Digging permits shall be required for excavations of 6 inches or deeper in accordance with LPR 1740.2.

1.5.8 Gas and Fumes

1.5.8.1 No one shall smoke, strike matches, or permit any other type of open flame in, or in close proximity to, a manhole or vault being ventilated until tests have determined that it is safe from gases or fumes.

1.5.8.2 Before entering a manhole or vault, forced ventilation shall be provided or appropriate gas detection tests (approved by the LaRC Safety Manager) shall be performed. If gas or fumes are detected, no one shall enter the manhole or vault (except as provided for in Paragraph 1.5.8.5) until thorough ventilation has been accomplished and tests made to ascertain that the gases or fumes have been eliminated.

1.5.8.3 When ventilating a manhole or vault to eliminate gases or fumes, the manholes on either side shall be opened when practicable.

1.5.8.4 Except where forced ventilation is provided, gas tests shall be made at regular intervals when underground work is in progress in manholes, hand holes, and vaults. If gases or fumes are detected, the manhole or vault shall be vacated promptly, ventilation started, and the condition reported to the supervisor.

1.5.8.5 If it should become necessary to perform work in a manhole or vault containing gases or fumes, no one shall enter except under direct authorization of the LaRC Safety Manager. The LaRC Safety Manager's representative shall be present and responsible for seeing that approved respiratory protective equipment and ventilation equipment are used.

1.5.9 Energized Cables in Manholes

1.5.9.1 All cables in manholes shall be considered as sources of potential shock and arc flash. Tests shall be made to verify that there is no voltage between the outer sheaths and grounds.

1.5.9.2 Even though cables are shown to have no potential between their outer sheath and ground, contact shall be avoided unless necessary to complete some specific item of work. High voltage gloves shall be worn unless the cable has been de-energized.

1.5.9.3 When working around energized cables in manholes, a physical barrier shall be provided to prevent contact of new cables, equipment or personnel with the existing energized cables. If energized cables cannot be physically isolated such that barriers can be installed to prevent potential arc flash hazards created by inadvertent contact with the energized cables, appropriate arc flash PPE shall be utilized.

1.5.9.4 Only qualified workers shall be permitted to work in electrical manholes or cable tunnels if energized cables are present. Unqualified workers may assist in these operations if adequate supervision and safety guarding of the unqualified worker is provided.

1.5.9.5 The conductive sheathing or shielding tape of all energized cables adjacent to the underground work area shall be verified to be grounded prior to commencing work. If ground verification is not feasible, then barriers shall be installed to prevent workers from making contact with energized cables or equipment. If neither barrier erection nor ground verification is feasible, all cables adjacent to the work area shall be de-energized.

1.5.10 Cutting and Splicing Power Cables

1.5.10.1 Splicing or taping of energized power cables shall not be permitted.

1.5.10.2 Before cutting into de-energized high voltage cables (above 600 volts) for the purpose of making repairs or removing the cables from the raceway system, workers shall also comply with the instructions elsewhere in these procedural requirements covering clearing, tagging, testing, grounding, and short circuiting, and shall also comply with the following requirements.

1.5.10.3 Before spiking or cutting, cables shall be identified by tags, ducts, and/or duct records. Tags and ducts associated with the cables shall be checked against records. Physical checks will be made on either side of the location where the work is to be performed. When the ends of the high voltage power cable are accessible and can be "open circuited," apply a pulsating test current to

the conductor and use a current measuring instrument to positively identify the cable. After the cable has been identified, either procedure "A" or "B" shall be followed to ensure that the cable is de-energized. After spiking, if no voltage is detected, the cable may be cut. Workers shall be located outside of the manhole during remote spiking or cutting of cables located in a manhole.

1.5.10.4 PROCEDURE “A”

(a) Spike the cable by using a remotely operated grounded, spiking device. The spiking device shall be installed on the cable using rubber gloves or an insulated stick and shall be actuated remotely by an insulated stick or by a hydraulically actuated or other mechanically actuating device. A spiking device that cuts through the cable is permitted provided that the cutting head is grounded.

1.5.10.5 PROCEDURE “B”

(a) Rubber gloves shall be worn when removing sheathing or shielding tape, when testing for voltage, and when cutting or spiking cables.

(b) A metallic jumper shall be installed to bond the metallic sheathing or shielding tape on each side of the proposed location for cutting the cable.

(c) At least 10 inches of sheathing or shielding tape shall be removed for the full circumference of the cable without disturbing the insulation. The cable shall then be tested for voltage with a voltage detector. The voltage detector shall be given a reliability test before and after the voltage test.

(d) If no voltage is detected, one-half of the insulation shall be removed. Test the cable for voltage. If no voltage is detected, the cable may be spiked with a remotely actuated, grounded spiking device. A spiking device that cuts through the cable is permitted provided that the cutting head is grounded.

1.5.11 Racking Medium and High Voltage Circuit Breakers

1.5.11.1 Racking of medium and high voltage circuit breakers for clearance to work on electrical circuits or during facility operations shall be performed by personnel who have been certified as Safety Operators for the specific equipment in accordance with LPR 1710.10.

1.5.11.2 The buddy system shall be used during the “rack in” or “rack out” of a circuit breaker.

1.5.11.3 Circuit breakers shall not be racked into operating position with the closing springs charged or fully compressed.

1.5.11.4 All unqualified personnel shall be cleared from the immediate and adjacent areas during racking operations, a minimum distance no less than the “Flash Protection Boundary” for flash protection defined by NFPA 70E, Art. 130.3(A) and Paragraph 4.1.5 of this document.

1.5.11.5 Appropriate PPE shall be selected and used during racking operations.

1.5.12 High Voltage Switching

1.5.12.1 All electrical switching required for clearance to work on electrical circuits shall be performed by personnel who have been certified as Safety Operators for the specific equipment in accordance with LPR 1710.10.

1.5.12.2 Appropriate PPE shall be used when operating high-voltage disconnecting switches. The minimum clear insulating length for disconnect poles shall be in accordance with OSHA 29 CFR 1926.950, Table V-1 and as indicated below. The minimum length for disconnect poles is the combination of minimum clear insulating length between the head and protective collar (or identifying mark) and the minimum handle length for the applicable voltage range.

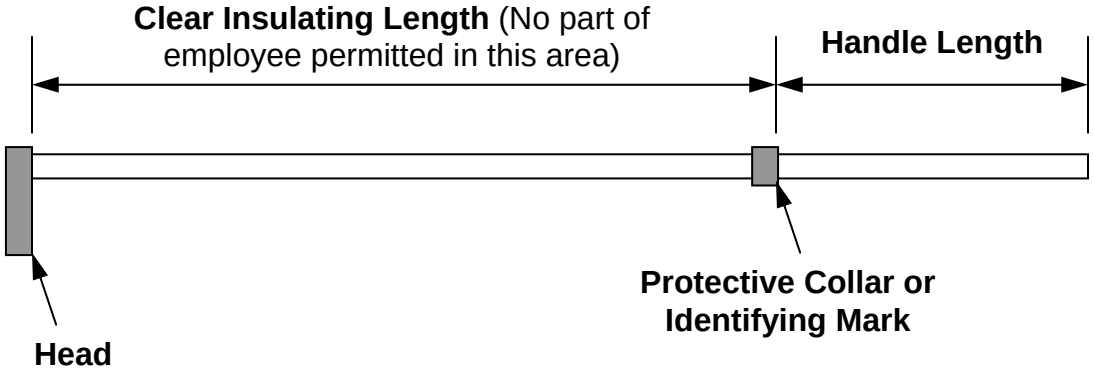

Figure 1.5.12.2 – Lengths for Disconnect Poles

	Minimum Disconnect Pole Lengths		
Voltage Range (Phase to Phase)	**Minimum Clear Insulating Length**	**Minimum Handle Length**	**Minimum Pole Length**
601 to 2,000	2 ft	1 ft	3 ft
2,100 to 15,000	2 ft	1 ft 8 in	3 ft 8 in
15,100 to 35,000	2 ft 4 in	2 ft	4 ft 4 in
35,100 to 46,000	2 ft 6 in	2 ft	4 ft 6 in
72,600 to 121,000	3 ft 4 in	2 ft 2 in	5 ft 6 in

1.5.12.3 When work is to be performed on secondary circuits or equipment, which are only disconnected from sources of power by switches with non-visible contacts, the following procedures shall be incorporated into the NASA Langley Form 495, "Safety Operator Clearances Procedure," associated with each switch being locked and tagged:

(a) Obtain concurrence from qualified electrical technician and the Facility Coordinator.

(b) De-energize the switch.

(c) Perform tests to verify that there is no voltage on the secondary circuits where the work is to be performed. Tests shall measure voltage from phase-to-phase and from each phase-to-ground.

(d) Apply lockout/tagout(s). Indicate on the red tag(s) that no work shall be performed on the high voltage (primary) side of the equipment.

(e) Apply protective grounding as close as physically possible to the secondary circuit power source.

(f) Before operating any switch used for maintenance or for isolating circuits above 600 volts, the switch operator is to be accompanied by a second electrically qualified person who is to stand at a safe distance and be prepared to respond in the event of an emergency.

2 TRAINING REQUIREMENTS

2.1 Technical Training

2.1.1 Qualified workers shall be technically trained and experienced in the work methods required by their electrical work assignments and shall have safety training on the operation of the equipment and the use of safe work practices.

2.1.2 Technical training commensurate with the assignments of the qualified worker shall be documented and shall meet the requirements of the workers job description. Refresher technical training shall be taken as required by the qualified worker's job assignments and certification requirements.

2.1.3 An individual that is undergoing on-the-job technical training and that has demonstrated competence in performing work safely shall be considered "qualified" if the individual is under the direct supervision of a "qualified" worker. This individual shall have completed safety training on the hazards involved prior to performing the work.

2.2 Safety Training

2.2.1 The direct supervisor of any person who works with electrical equipment shall ensure that the person has completed the minimum safety training defined below. The level of safety training shall be based on the level of electrical risk and hazard to which the worker will be exposed.

	Required Training	Type and Frequency	
		Initial	Every 3 Years
Qualified Workers, Less Than 600 V	• NFPA 70E • Low Voltage Safety	Comprehensive	Refresher
Qualified Workers, Over 600 V	• NFPA 70E • Low Voltage Safety • High Voltage Safety	Comprehensive	Refresher
Unqualified Workers	• NFPA 70E	Comprehensive	Refresher

2.2.2 Safety training for qualified workers shall include as a minimum:

(a) Training in the skills and techniques to distinguish exposed energized parts from other parts of the electrical equipment

(b) Training in the skills and techniques necessary to determine the nominal system voltage of the exposed energized part

(c) Training to determine the minimum approach distances to exposed energized parts as specified in NFPA 70E, Table 130.2(C) and Sections 4.1.4 and 4.1.5 of this document

(d) Training to determine the degree and extent of an electrical hazard and in the proper use of PPE required to perform the task safely

2.3 Additional Training

2.3.1 Electrical Safety Operators shall meet the training and qualification requirements for Safety Operator Certification as required by LPR 1710.10, Chapter 6, “Safety Operators”.

2.3.2 Non-Electrical Safety Operators performing electrical lockout/tagout for mechanical equipment operating at less than 600 volts shall complete the safety training for qualified workers as defined in Paragraph 2.2.1.

3 ELECTRICAL SYSTEM DOCUMENTATION REQUIREMENTS

3.1 Area of Responsibility

3.1.1 It shall be the responsibility of the person or group preparing design drawings to initiate action to document changes to the electrical drawings described in the following paragraphs. In the event that changes are made to the electrical system and drawings are not produced prior to the changes, the personnel performing the work shall be responsible for preparing drawings of such detail that the information can be entered onto the record drawings.

3.2 Configuration Management

3.2.1 LPR 1740.4, “Facility System Safety Analysis and Configuration Management,” defines the Configuration Management (CM) Program. It also identifies the facilities, which are under CM and defines the minimum electrical drawings required for these facilities. No changes shall be made to these drawings or equipment without the changes conforming to the requirements of LPR 1740.4.

3.2.2 It is the intent for all drawings and diagrams included in the CM program to be updated to the “as-built” configuration. It is recognized that this is a difficult and expensive process. The updating of the drawings is currently a requirement of the Research Operation, Maintenance and Engineering (ROME) contract. The schedule for updating the drawings will be based on the approved drawing update schedule in accordance with the requirements of the ROME contract.

3.3 Type of Drawings

3.3.1 Switching and Metering One Line Diagrams (Effort Code 300)

3.3.1.1 Switching and metering one line diagrams shall be maintained in LaRC’s Configuration Management On-Line (CMOL) system under Effort Code 300. These drawings shall be kept in an ”as-built” condition as defined by LPR 1740.4.

3.3.1.2 The list of disconnect devices (switches, circuit breakers, etc.) shall be included in Effort Code 300 as a device list.

3.3.1.3 The following cable and switch legend applies to the switching diagrams:

Series Number	Voltage Level
1000	115 kV
2000	22 kV
3000	6.6 kV and 6.9 kV
4000	2.4 kV
5000	125 VDC and 115 VAC
6000	120/208 V
7000	277/480 V
8000	4.16 kV and 4.6 kV (Variable Frequency)
9000	13.8 kV
9500	34.5 kV

3.3.2 Manhole Drawings (Effort Code 301)

3.3.2.1 Manhole drawings shall be maintained in LaRC's CMOL system under Effort Code 301. These drawings shall be kept in an "as-built" condition as defined by LPR 1740.4.

3.3.3 Building Drawings - Low Voltage One Line Diagrams (Effort Code 302)

3.3.3.1 Building drawings (low voltage one line diagrams) shall be maintained in LaRC's CMOL system under Effort Code 302. As a minimum, building drawings shall include single line diagrams of the 208 volt and 480 volt power distribution system and floor plans showing the location of the power distribution equipment (transformers, panelboards, switching centers, motor controls centers, etc.) The single line diagrams shall reference the applicable high voltage switching diagram maintained in CMOL under Effort Code 300. These drawings shall be kept in an "as-built" condition as defined by LPR 1740.4.

3.3.4 Major Electrical Substation Drawings (Effort Code 303)

3.3.4.1 Major electrical substation drawings shall be maintained in LaRC's CMOL system under Effort Code 303. These drawings shall be kept in an "as-built" condition as defined by LPR 1740.4. Major electrical substations are delineated in the Stratton Substation Facility Resume under Appendix 3.

3.3.5 Underground Utilities Drawings

3.3.5.1 Underground systems, because of their high potential for damage during excavation and the associated danger to personnel performing work on these systems, have special requirements. LPR 1740.2, “Facility Safety Requirements,” defines the requirements for “as-built” drawings. The locations of underground electrical systems shall be documented on drawings in the LaRC Facility Utilities Electronic Database (FUED) system. These drawings are not included in the CMOL system.

3.3.6 System Design Drawings

3.3.6.1 Drawings for facilities not under the CM Program may not be up-to-date and should be field verified for accuracy prior to designing or implementing any changes. The following “as-built” documentation should be provided for each system/building which is not included in the CM Program:

(a) A control criteria document that includes sign off by the design engineers for each discipline involved and which identifies the basic interlock logic needed to assure safe and practical control for each process system

(b) An overall system functional or block diagram clearly describing the engineering design intent for each system giving the function of each major component

(c) System schematics and/or elementary wiring diagrams, including one-line distribution diagrams for building power systems including the building unit substation, secondary breakers, panelboards, and motor control centers

(d) Individual equipment wiring diagrams and interconnection drawings showing each terminal strip connection, excluding building light and power panels

(e) Panel schedules for building light and power

(f) Facility location or plot plans showing all basic equipment, panelboards, motor control centers, main distribution panels, unit substations, and major facility equipment

3.3.7 On-Site Drawings

3.3.7.1 Except as defined for facilities in the LaRC CMOL system, it is the responsibility of the respective Facility Coordinator to determine the type and location of drawings to be kept on-site.

3.4 Drawing Distribution

3.4.1 Copies of Effort Code 300 switching diagrams for the high-voltage power distribution system (over 600 volts) shall be distributed to personnel on a list approved by the Chairperson of the Electrical Systems Committee who shall assure that corrected copies of drawings affected by modifications are promptly provided to holders of switching diagram sets. In addition, electronic copies of these diagrams are included in the LaRC CMOL system and are accessible for viewing and making copies (but not revising) by LaRC employees who have been assigned an appropriate computer access password. The Center Operations Directorate has the responsibility for initiating Change Notification Sheets (CNS) for updating the electronic copies on CMOL.

3.4.2 Copies of other drawings will be distributed to personnel as defined in LPR 1740.4 and/or as determined by the Chairperson of the Electrical Systems Committee.

3.5 Equipment Operating Procedures

3.5.1 Each facility with complex or high energy systems shall have written operating procedures to ensure the safety of personnel and the protection of equipment. These procedures include, but are not limited to, operating sequences, safety precautions, and emergency actions required. (LPR 1740.4 defines the requirements for operating procedures, records, etc.)

4 OPERATIONS AND MAINTENANCE REQUIREMENTS

4.1 General

4.1.1 Color Coding – Indicating Lights

4.1.1.1 The color of indicating lights designating the condition or position of the contacts on circuit breakers or switches for new or modified systems shall conform with the following:

(a) Contacts closed – red

(b) Contacts open – green

(c) Contact automatically tripped open - amber

Note 1: The above color coding of indicator lights is specific to switchgear as referenced in IEEE C37.11 and C37.100.

4.1.1.2 The color of indicating lights designating the position of valves that allow flow or block flow shall conform with the following:

(a) Allows flow – green

(b) Blocks flow - red

4.1.1.3 The required designation as indicated here may be waived by the LaRC Safety Manager if, for reason of prior usage in a facility, it is deemed safer to use other designations. This special ruling shall require written notification and approval from the LaRC Safety Manager.

4.1.1.4 The color coding of indicating lights (and pushbuttons) for industrial control systems is not consistent throughout industry, nor is it consistent for facility control systems at LaRC. The color coding of indicating lights (and pushbuttons) for control systems within a facility shall be consistent. Existing control systems are not required to be updated to meet this requirement unless they are being modified or upgraded, at which time they shall utilize the prevailing color scheme for control systems within the facility. Guidance for color coding or indicator lights (and pushbuttons) may be found in NFPA 79, IEC 60204-1, and IEC 60073.

4.1.2 Control Voltages for Devices

4.1.2.1 All controls subject to “routine” operational adjustments of exposed electrical components or controls that are not packaged in a manner to preclude casual

or random entry by unauthorized individuals shall conform to the NEC Art. 725 for Low Energy Power and/or Low Voltage Power Circuits.

4.1.3 Working Space Around Equipment

4.1.3.1 Sufficient access and working space shall be provided and maintained around all electrical equipment to permit ready and safe operation and maintenance of such equipment.

4.1.3.2 Working space around electrical equipment shall be based on providing sufficient clearance to avoid body contact with grounded parts while performing maintenance on energized equipment.

4.1.3.3 Minimum working space around equipment operating at 600 volts or less and working space entrance requirements shall be as required by the NEC, Art. 110.32 through 110.34.

4.1.3.4 Except for substations, the minimum working space around equipment operating over 600 volts shall be as required by the NEC, Art. 110.32. For substation locations, the minimum working space shall be as required by ANSI/IEEE C2-NESC, Rule 125.B.

4.1.4 Approach Distances to Exposed Energized Parts – Shock Protection

4.1.4.1 NFPA 70E defines three shock protection boundaries (Limited Approach Boundary, Restricted Approach Boundary, and Prohibited Approach Boundary) for workers approaching exposed energized parts. The distances for these boundaries, (based on system voltage) are listed in NFPA 70E, Table 130.2(C). The requirements for crossing the shock protection boundaries by qualified and unqualified persons are defined in NFPA 70E, Art. 130.2, summarized in the table below, and illustrated in Figure 4.1.4.1.

	Boundary Crossing Requirement based on Worker Qualifications	
Shock Protection Boundary	**Unqualified Worker**	**Qualified Worker**
Limited Approach Boundary	Prohibited from crossing unless escorted by qualified worker	Permitted to cross
Restricted Approach Boundary	Prohibited from crossing	Prohibited from crossing except as permitted by NFPA 70E, Art. 130.2 (C) and Paragraph 4.1.4.2 below
Prohibited Approach Boundary	Prohibited from crossing	Crossing this distance treated the same as making contact with energized parts

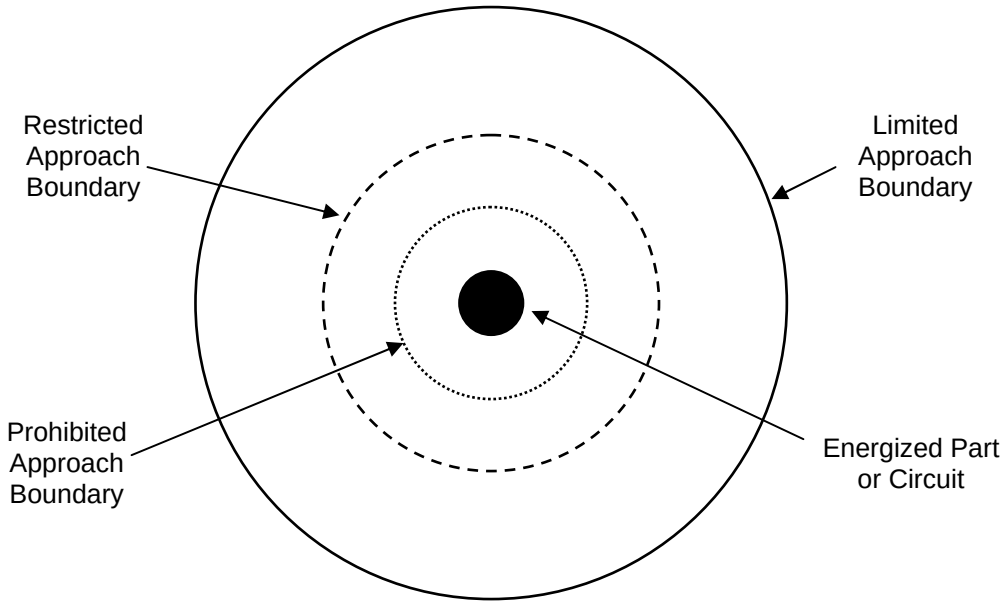

Figure 4.1.4.1 – Boundaries for Shock Hazard Protection Based on System Voltage Levels

4.1.4.2 Electrically qualified workers shall not approach or take any conductive object closer to exposed energized parts than the "Restricted Approach Boundary" defined in NFPA 70E, Table 130.2(C) and listed below, for any reason unless such parts are adequately guarded as required by NFPA 70E, Art. 130.2(C). Voltage ranges shown are those applicable to systems at LaRC.

Nominal System Voltage Range - Phase-to-Phase	Distance from Energized Parts to Restricted Approach Boundary
50 – 300 volts	Avoid contact
301 - 750 volts	1 ft
751 - 15,000 volts	2 ft 2 in
15,100 – 36,000 volts	2 ft 7 in
36,100 – 46,000 volts	2 ft 9 in
72,600 – 121,000 volts	3 ft 3 in

4.1.5 Approach Distances to Exposed Energized Parts – Arc Flash Protection

4.1.5.1 If work on or near exposed energized parts is required, as permitted by Paragraph 1.4.1.1, flash protection PPE shall be utilized as required by NFPA 70E, Art. 130.3(B).

4.1.5.2 The need for and level of flash protection PPE is determined by whether or not the worker is closer than the Flash Protection Boundary (FPB) and what the available Incident Energy (IE) level is at the Working Distance (WD) from the exposed energized part resulting from an arc flash. FPB and WD are illustrated in Figure 4.1.5.2.

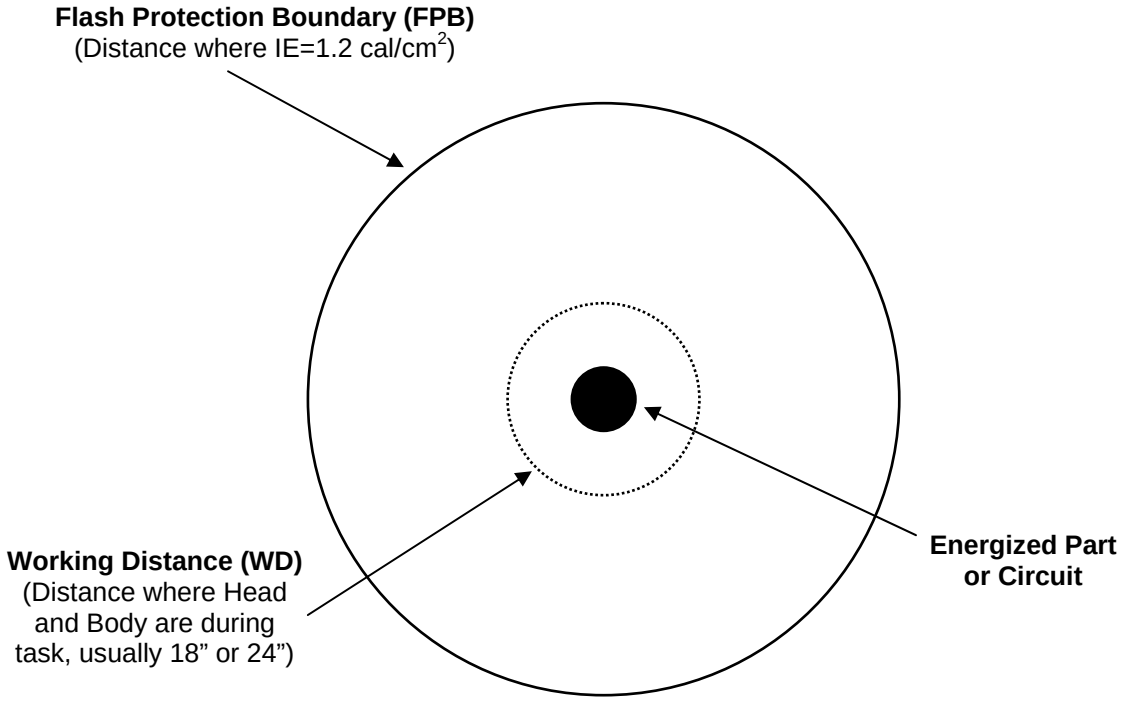

Figure 4.1.5.2 – Boundaries for Arc – Flash Protection Based on Arc Flash Incident Energy Levels

4.1.5.3 The FPB is the distance that the incident energy is no greater than 1.2 cal/cm^2, which is the energy that will result in a second degree burn when not using arc flash PPE. For systems that are 600 volts or less, the FPB is 4 ft. (assuming a maximum available bolted fault current of 50 kA and a 6 cycle clearing time) unless marked on the equipment by an arc flash hazard label. Alternatively, and for equipment operating above 600 volts, NFPA 70E, Art. 130.3(A) may be used to calculate the FPB or contact the Electrical Standard Practice Engineer to obtain this distance.

4.1.5.4 The WD is the distance between the worker's head or body and the exposed energized part for the specific task. The WD for electrical tasks is 18", unless specifically marked on the equipment as 24".

4.1.5.5 Incident energy levels for the selection of PPE shall be based on the calculated energy level at the working distance for the task. If not marked on the equipment by an arc flash hazard label, the incident energy level can be obtained from the Electrical Standard Practice Engineer. The Hazard/Risk categories based on incident energy levels are listed in NFPA 70E, Table 130.7(C)(11). Alternatively, NFPA 70E, Table 130.7(C)(9)(A) may be used to select PPE for various electrical tasks in lieu of calculating incident energy levels at the WD. (See Appendices A and C.)

Note 1: Flash Protection PPE does not prevent injury resulting from an arc flash. It is designed only to limit the injury resulting from an arc flash to a second degree burn, which has been determined to be a survivable burn.

4.1.6 High Voltage Verification Test Conditions

4.1.6.1 High voltage dielectric testing shall be preceded by the following actions:

(a) Red tag the applicable circuits

(b) Check for absence of voltage

(c) Secure the area

(d) Perform a low voltage dielectric test (Megger test)

(e) Perform grounding procedures

4.1.6.2 During these tests all safety precautions listed in Section 6, Paragraph 6.9 of ANSI/IEEE 95-1977 shall be followed.

4.1.6.3 Operational electrical equipment shall be periodically validated to determine that the dielectric strength has not fallen below safe levels. The responsible operations group shall maintain procedures specifying the method and frequency of the tests. A DC "Megger" appropriate to the circuit working voltage shall be used to obtain the readings. Validation is mandatory prior to energizing after any repair, which may have affected the equipment insulation system. In general, power system equipment shall be tested for minimum values of 1 megohm or 1 megohm per 1000 volts of operating voltage, whichever is greater. If lesser values are obtained, an appraisal shall be made by the responsible engineering organization before the equipment is energized.

4.1.7 Cranes and Lifting Equipment Adjacent to Exposed Electrical Energized Parts

4.1.7.1 Where cranes or other lifting equipment are used in or around high-voltage substations, overhead lines, or exposed energized parts, the operations and equipment shall be in conformance with OSHA 29 CFR 1926.550. See Paragraph 4.3.1.6 for additional requirements on crane usage.

4.1.7.2 All lifting equipment shall be effectively grounded when being moved or operated in close proximity to energized lines or equipment. Consideration shall also be given to grounding the load, particularly if insulated lifting straps are in use.

4.1.7.3 Lifting equipment shall be operated with a dedicated observer to warn the equipment operator of potentially hazardous situations and/or movements.

4.1.7.4 Exposed energized conductors of up to 115kV are in use in high-voltage substations at LaRC. The following clearances shall be maintained between cranes and lifting equipment and exposed energized conductors as required by OSHA 29 CFR 1926.550(a)(15):

Conductor Voltage	Minimum distance between conductors and equipment
50 kV and below	10 ft
115 kV	12 ft, 2 in (Note 1)

Note 1: Distance calculated for 115 kV based on requirements from OSHA 29 CFR 1926.550(a)(15). See this standard for distance requirements for voltages other than those shown here.

4.2 Facilities and Equipment

4.2.1 General Requirements

4.2.1.1 A daily log shall be maintained at each facility, which has major electrical systems. The Electrical Standard Practice Engineer shall determine which facilities are required to maintain a daily log. This log shall record pertinent information for each operating shift, including as a minimum: operator's name, time of entry, explanation of any equipment malfunction or unusual operation, and any special work performed on the equipment.

4.2.2 Installation or Major Repair – General

4.2.2.1 Prior to selecting and installing any new electrical equipment or systems, the design engineer shall consult and coordinate the work with the Facility Safety Head.

4.2.2.2 The Facility Safety Head shall be responsible for the overview of safety aspects for the repair or overhaul of major research equipment, which requires partially or totally disabling of the research operations of a facility.

4.2.3 Installation or Repair of Transformers

4.2.3.1 Whenever work is to be performed on connected transformers, protective grounds shall be applied as required by Paragraph 1.5.3 of this document.

4.2.3.2 When transformers are installed or replaced, the secondaries shall be checked for correct voltage and phase rotation.

4.2.3.3 When transformers are installed and before they are energized, the ground connection shall be made to the case, and where applicable, to the neutral.

4.2.3.4 Transformer covers or hand hole plates shall not be removed from energized transformers.

4.2.3.5 All transformers shall be considered energized at full voltage unless they are disconnected from the primary and secondary power source, or unless they are disconnected from the primary power source and protective grounds have been applied to the transformer secondary. The opening of a fused primary cutout or switch shall not be considered as a primary disconnection unless the de-energized side of the cutout or switch is grounded.

4.2.3.6 When removing transformers, the case and neutral ground shall be disconnected last.

4.2.3.7 Because it is possible to have up to full phase-to-ground voltage on the transformer neutral, transformer neutrals shall always be treated as phase conductors, unless established as grounded.

4.2.4 Removal of Obsolete Equipment

4.2.4.1 Unless otherwise specified in a contract or requested by the Facility Coordinator, when removing old or obsolete equipment, the electrical wiring, conduit, and control boxes shall be removed from the equipment to the power source. The power source shall be de-energized and disconnected prior to disconnecting the load or cutting the cables.

4.2.4.2 After the equipment has been removed, the controlled electrical wiring diagrams, schematics, and so forth, shall be revised to show this change. See Section 3 for documentation update requirements.

4.2.5 Control Systems

4.2.5.1 Whenever control systems are dependent on electrical power for safe operation, provisions shall be made to have these systems operate to the failsafe position in the event of an electrical power failure.

4.2.6 Standby Electrical Power

4.2.6.1 A minimum of two 60-kW or larger diesel electric or equivalent portable power plants shall be available for emergency use. This power shall be provided at a voltage rating of 480 volts and/or 208 volts, three-phase, 60 Hertz that will permit connections to the bus on the secondary side of building unit substations.

4.2.7 Contractor Connections into Government Electrical Utilities

4.2.7.1 Prior to permitting the contractor to make connection into any part of the Government electrical power distribution system, the contractor shall:

4 Make written application to the Government Contracting Officer stating the date, time, location, and the service desired.

5 Jointly with the Government representative, make the necessary checks of the contractor's system and the Government’s supply to ensure their compatibility and safety.

4.2.8 Initial Energization of Electrical Systems Above 600 Volts

4.2.8.1 Initial energizing of all new electrical equipment shall be performed in the presence of the appropriate Government representative.

4.2.8.2 All power feeder circuit breakers shall be checked for adjustment and operation in accordance with the manufacturer's instructions. Molded case circuit breakers without solid state trip devices are excluded from this requirement.

4.2.8.3 All protective relays and other such devices shall be tested to verify their capability of operating in the range required. Where possible, tests shall include “loading in” at the current transformer secondaries to validate the circuitry as well as the device.

4.2.8.4 All wiring shall be field verified for conformity to the design, fabrication, and functional requirements.

4.2.8.5 All electrical equipment shall be tested in accordance with industry standards at voltage levels approved for the specific type of equipment by the LaRC cognizant engineering group or approved designee. In general, the minimum acceptable insulation resistance for electrical equipment shall be the greater of 1 megohm or 1 megohm per 1000 volts of operating voltage.

4.2.9 Protective Relay Settings

4.2.9.1 Protective relay settings shall be coordinated and concurred with by the Electrical Standard Practice Engineer to provide selective tripping. The responsible electrical engineering organization shall review and approve the coordination. The responsible operations organization shall maintain a listing of the required settings and the frequency of periodic testing of all protective relays in use.

4.2.9.2 All protective relays for 22 kV and 115 kV circuits on the LaRC power system shall be checked and calibrated once every two years. Protective relays for circuits less than 22 kV shall be checked and calibrated once every four years. Every reasonable effort shall be made to perform an end-to-end check of the relay circuitry in the process of this check.

4.2.10 Circuit Interruption Devices

4.2.10.1 All circuit interruption devices shall be rated to interrupt the maximum short circuit current of the power system at the point of application of the device.

4.2.10.2 Short circuit system studies shall be made by the responsible electrical engineering organization and concurred with by the Electrical Standard Practice Engineer to obtain data on short circuit interrupting duty requirements whenever large loads are added or major system changes are made which may affect the short circuit duty of the circuit breakers on the LaRC power distribution system.

4.2.10.3 Circuit breakers shall be immediately inspected and checked to assure suitability for reuse after any operation in which the circuit breaker opens under short circuit or fault conditions. When a trip occurs on breakers above 600 volts, the troubleshooting process shall verify the settings of all breakers between the fault and the breaker, which tripped. Molded case circuit breakers without solid state trip devices are excluded from this requirement.

4.2.10.4 All 115 kV circuit breakers shall be operated at least once every 24 months to assure satisfactory mechanical operation.

4.2.11 Infrared (IR) Thermography

4.2.11.1 Infrared Thermography of electrical systems 600 volts or below may be performed by a thermographer who is not electrically qualified provided that an electrically qualified person is present anytime an electrical panel is open to exposed energized conductors, the thermographer is certified, has received the appropriate NFPA 70E training, and stays outside the approach distances specified in NFPA 70E.

4.2.11.2 Infrared Thermography of electrical systems exceeding 600 volts may be performed by a thermographer who is not electrically qualified provided there are two electrically qualified personnel present anytime an electrical panel is open to exposed energized conductors, the thermographer is certified, has received the appropriate NFPA 70E training, an approved form LF 416 is in place, and stays outside of the approach distances specified in NFPA 70E.

4.2.11.3 Infrared Thermography of overhead connections in substations may be performed by a thermographer who is not electrically qualified provided that an electrically qualified person is present, the thermographer is certified, has received the appropriate NFPA 70E training, and stays outside of the approach distances specified in NFPA 70E.

4.3 Work in Energized Substations

4.3.1 General Requirements

4.3.1.1 In addition to the other industry electrical safety codes, rules, and regulations specified elsewhere in this document, work in energized substations shall comply with the requirements of ANSI/IEEE C2-NESC, all applicable OSHA standards for substations, and Section 1.5 of this document.

4.3.1.2 Work areas shall be clearly defined by the installation of barriers and rope guards. Barriers and rope guards shall be sufficient to restrain the workers from inadvertently moving out of the work area.

4.3.1.3 Use physical barriers whenever practicable. When adequate barriers cannot be installed around all energized parts adjacent to the work area, action shall be taken to provide the continuous safeguarding of each worker.

4.3.1.4 Establish a safe zone area between the work area and the energized parts of the substation so that all live circuits and parts clear the designated work area by at least five feet.

4.3.1.5 Electric power outages required to execute work in the substation shall be requested at least seven days in advance of the need.

4.3.1.6 Refrain from using any crane in or near an energized substation with exposed conductors where movement of the crane might cause objects to fall into or strike energized parts of the substation. If crane usage is required to support the work, a power outage shall be requested for the work area. See Section 4.1.7 for clearance requirements for cranes working around exposed energized conductors.

4.3.1.7 When work involves handling of lengths of conduit, bus, steel, or large equipment in substations with exposed energized bus, a full-time employee knowledgeable of the safety required and without other duties shall be assigned to assure the safety of the work area.

4.3.1.8 After execution of a power outage by an LaRC certified Safety Operator as evidenced by receipt of the red tag stubs the lockout/tagout responsible person shall check to ensure the designated circuits have been de-energized and properly grounded and verify that the immediate work area and a zone beyond the work area have been made safe before permitting employees to work in the substations.

4.3.1.9 Additional safety supervisors shall be assigned as needed for the protection of the workers when the work is so divided and extensive that one safety supervisor cannot effectively maintain safety surveillance over the workers and their operations.

4.3.2 Contractors other than NPS Contractors

4.3.2.1 Except for Non-Personal Service (NPS) Contractors that provide on-site operational and maintenance support for electrical systems at LaRC, contractors who are required to enter and/or work in energized substations shall comply with the following requirements in additional to the requirements of Section 4.3.1 above.

4.3.2.2 Submit a work plan, at least seven days prior to initiating work in the substation, outlining the work to be done and identifying the circuits required to be de-energized to safely conduct operations. The plan shall include a detailed step-by-step work procedure for each phase of the work. All changes to this work plan shall be reviewed with the responsible LaRC personnel prior to initiation.

4.3.2.3 Appoint an individual responsible for the electrical safety of each work team. The safety supervisor(s) shall attend the Construction Safety Briefing. Before the work begins, the responsible individual shall provide a document to the Government establishing that the appointed safety supervisor(s) is (are) qualified and knowledgeable in OSHA and LaRC safety regulations and requirements.

4.3.2.4 Contact the Government representative at the beginning of work each day for admittance to the substation. Maintain surveillance of the substation gates to only permit authorized personnel to enter. No entrance shall be made while work is being conducted unless the contractor safety supervisor has been first contacted to verify conditions are safe.

4.4 Substation Access

4.4.1 Standard Substation Access Procedures

4.4.1.1 Doors and gates that control access to high voltage substations are secured with locks. Keys for these locks are assigned to qualified “key” holders who are electrically qualified personnel who have a need to enter the substations on a regular basis.

4.4.1.2 The issuance of substation keys shall be approved by the power distribution system Facility Safety Head and Facility Coordinator, and the Electrical Standard Practice Engineer.

4.4.1.3 Temporary keys may be assigned to other electrically qualified personnel at the discretion of the power distribution system Facility Safety Head and Facility Coordinator, and the Electrical Standard Practice Engineer.

4.4.1.4 Personnel who require access to the substations but are not a qualified “key” holder shall contact a qualified “key” holder who shall escort anyone they permit into the substation.

4.4.1.5 General requirements for substation entries are as follows:

(a) At least two people shall be involved in all entries into the substation when work is to be performed.

(b) Entry gates/doors shall be closed but shall remain unlocked while personnel are working in the substations.

(c) Entry gates/doors shall be locked when the last person exits the substation.

4.4.2 Substation Access for Non-Electrical Work

4.4.2.1 Unqualified personnel performing non-electrical work such as grounds keeping and painting in energized substations shall obtain substation access from a qualified “key” holder.

4.4.2.2 When the non-electrical work is performed around electrical hazards, the qualified “key” holder or another electrically qualified person shall act as a safety watch. If the electrical hazard can be eliminated by de-energizing

circuits, or securing access to circuits by padlocks or barriers, then the work can be performed with no electrically qualified person present.

5 SPECIAL EQUIPMENT HANDLING PROCEDURES

5.1 Batteries

5.1.1 Vented batteries and battery cells, regardless of electrode type, contain dangerous electrolytes, which are subject to spillage. Overcharging or too rapid charging can cause electrolyte boiling and spewing, and the production of explosive gases. The following requirements shall be followed in these devices:

(a) Face shields and goggles, rubber gloves, and protective rubber aprons shall be worn whenever batteries or cells are being handled, filled, or charged.

(b) Ample neutralizing agent shall be present to fully neutralize any electrolyte spill, which may occur in battery operations.

(c) Battery charging shall take place in a well ventilated area.

(d) No smoking shall be permitted in the area where batteries are handled, filled, or charged.

(e) Battery charging shall comply with all of the manufacturer’s recommendations.

(f) An eyewash station shall be in an accessible location that requires no more than 10 seconds to reach. This eyewash station can be in each facility or on the battery technician's truck. Eyewash devices shall comply with ANSI Z358.1-2004.

5.2 Fuses

5.2.1 Fuses shall not be removed on energized circuits above 23,000 volts. Fuses shall not be removed from loaded energized circuits with voltage ranges from 50 volts to 23,000 volts. In addition to the PPE requirements of NFPA 70E when removing or replacing fuses on unloaded energized circuits, the following shall be required:

(a) Rated 50 to 600 volts, insulated fuse tongs, extractors, or other approved methods shall be used.

(b) Rated 601 to 1000 volts, lineman's type rubber gloves in addition to either insulated fuse tongs or extractors shall be used.

(c) Rated 1001 to 23,000 volts, lineman's type rubber gloves in addition to insulated high-voltage sticks or tongs shall be used.

5.3 Experimental Equipment – General

5.3.1 Experimental electrical equipment that is under development, and therefore subject to frequent modifications, presents a particular hazard to personnel. Operating and emergency procedures may change from day to day. The following are minimum safety requirements:

5.3.2 A responsible member of the research team shall be designated to establish correct working procedures as well as proper emergency procedures for review and approval by the Electrical Standard Practice Engineer. Particular emphasis shall be placed on emergency de-energizing of the equipment.

5.3.3 Areas where high energy sources are present shall be marked and physical barriers used where practicable. Electrical and mechanical safety interlocks shall be used where practicable.

5.3.4 Persons shall not work alone on high energy equipment unless the electrical equipment has been de-energized and secured in an electrically safe work condition.

5.3.5 Before working on high voltage/high energy equipment that has been energized and then de-energized, after lockout/tagout has been implemented, the equipment shall be grounded to ensure no residual voltage remains as a potential shock hazard.

5.3.6 Use of high voltage capacitor banks on experimental equipment shall comply with the requirements of Paragraph 5.4 of this document.

5.3.7 Fail safe circuits shall be used, where practicable, in order to minimize possible hazards to personnel and equipment.

5.3.8 Temporary wiring shall meet the requirements of the NEC and Paragraphs 1.4.9 and 1.4.10 of this document. Indiscriminate use of extension cords and portable cables shall be avoided.

5.3.9 Do not use any equipment that has frayed cords or three-wire cord ends that have had the grounding prong removed. Faulty equipment and tools shall be repaired by qualified personnel.

5.3.10 The general and specific work requirements under Paragraphs 1.3 and 1.4 of this document shall apply to work under this paragraph.

5.3.11 Use of knockout boxes to house receptacles for an on-site extension cord shall not be permitted.

5.4 Experimental Equipment – High Voltage Capacitor Banks

5.4.1 Test personnel conducting experiments where capacitor banks with voltages above 600 volts are employed, shall have total knowledge of the experiment, the circuit and component layout, and be fully trained in the operating and safety procedures to be used at that facility, including procedures to be used in the event of equipment failure.

5.4.2 The high voltage test area shall be enclosed and protected through the use of gates and interlocks on the test controls. Capacitors and related high voltage component faults are a possible source of hazardous shrapnel. These components shall be isolated in a manner that precludes personnel injury or facility related hazards, such as fire.

5.4.3 High voltage warning signs shall be displayed in a conspicuous location. Flashing warning lights shall be used to indicate that tests are in progress.

5.4.4 A shorting switch or grounding device, which normally discharges the capacitor bank, shall be clearly visible to the test operator.

5.4.5 A voltmeter (VM) connected across the capacitor bank shall be clearly visible to the test operator at all times. A redundant VM shall be installed at the capacitor banks.

5.4.6 Prior to touching a high voltage component within the test area, a grounding wand approved by the LaRC Safety Manager for the particular installation shall be used to verify that the capacitor bank is fully discharged.

5.4.7 Extreme caution shall be used on capacitor banks that are operated by DC voltages since a DC capacitor bank will maintain a residual voltage for extended periods.

5.4.8 Capacitors that are connected in a series to form a bank shall be treated with great care, and prior to making any changes to a test bank or circuit, each capacitor in a series string shall be properly discharged.

5.5 PCB Hazards

5.5.1 Electrical equipment, such as transformers, capacitors, and so forth, may contain a highly toxic, noncombustible, synthetic, electrical insulating liquid known generically as “Polychlorinated Biphenyls” (PCB). PCB has been sold under various trade names including “Askeral,” "Inerteen,” “Chlorexol,” “Noflamal,” and “Pryranol.” All leaks of fluid containing PCB shall be reported immediately to the LaRC Environmental Manager.

6 HAZARDS OF ELECTRICITY

6.1 Hazards of Electric Arcs

6.1.1 Arc Flash

6.1.1.1 While the phenomena of electric arcs and their destructive forces is nothing new, their threat to the safety of exposed electrical workers has only recently come under close scrutiny. Because of the availability of high fault current levels in industrial systems, arcs from electric faults are more powerful and dangerous. An uncontrolled electric arc results in arc flash and arc blast. The severity of the hazard to the worker is determined by the amount of available energy at the fault and proximity of the worker to the fault. A dropped tool, deteriorating insulation on aging conductors, or animals are examples of situations that can create electric arc faults.

6.1.1.2 During a fault, conductive plasma is created that produces an arc flash at temperatures up to 35,000°F. The resulting radiated heat energy can create fatal burns or burns severe enough to result in long lost time recovery periods. Depending on the available short circuit current at the fault and the duration of the fault, the resulting incident energy (radiated heat energy) can exceed 40 cal/cm^2. An incident energy level of 1.2 cal/cm^2 will create a second degree burn causing very painful blistering of the skin, which has been deemed to be a survivable burn. A third degree burn results in complete destruction of the skin, cooking of the deeper tissues, and permanent damage and disfigurement.

6.1.1.3 Working on de-energized equipment will eliminate the arc hazard. If this is not possible, exposure to high incident energy levels while working on energized equipment can be mitigated by the use of flash rated PPE and increasing exposure distance. Flash protective PPE is designed to limit incident energy levels during an arc flash to 1.2 cal/cm^2. Requirements for arc flash hazard mitigation are found in the latest edition of the NEC and NFPA 70E, Art. 130.

6.1.2 Arc Blast

6.1.2.1 Arc blast is a second consequence of electric arcs. The arc blast is produced by the rapid expansion of super-heated air surrounding the arc and vaporization of conductive metal by the arc resulting in an explosive air pressure wave. The blast energy or pressure resulting from an electric arc blast can be significant enough to cause falls or impact injuries that are more severe than burn injuries. Water turning into steam expands to 1670 times its original volume. By comparison when copper vaporizes, it expands to 67,000 times its original volume. This is the same expansion rate that is produced

when dynamite explodes. Protective clothing will not protect against impact forces resulting from this blast pressure.

6.2 Hazards of Electric Shocks

6.2.1 Effects of Electric Shocks

6.2.1.1 Some individuals who handle electrical equipment mistakenly believe their tolerance to electric shock is related to their ability to withstand the pain of the shock. Actually, the lethal incidence is a function of current passage (duration and level) through the heart region. Additionally, the onset of possibly lethal currents is only marginally higher than those ranked just painful and well within the range of industrial low-voltage power systems. While asphyxiation is the physiological result of the first zone of over-painful shock, the second zone results in heart ventricular fibrillation, or heart dysfunction. Not only is the latter not self-curing on cessation of the current, but it is generally lethal within about 3 minutes. Just as it is current, not voltage, which heats a wire, it is current which causes the physiological damage.

6.2.1.2 The values of 60 Hz current and its effects (typically) on an average man are listed in Figure 6.2.1.2 as follows:

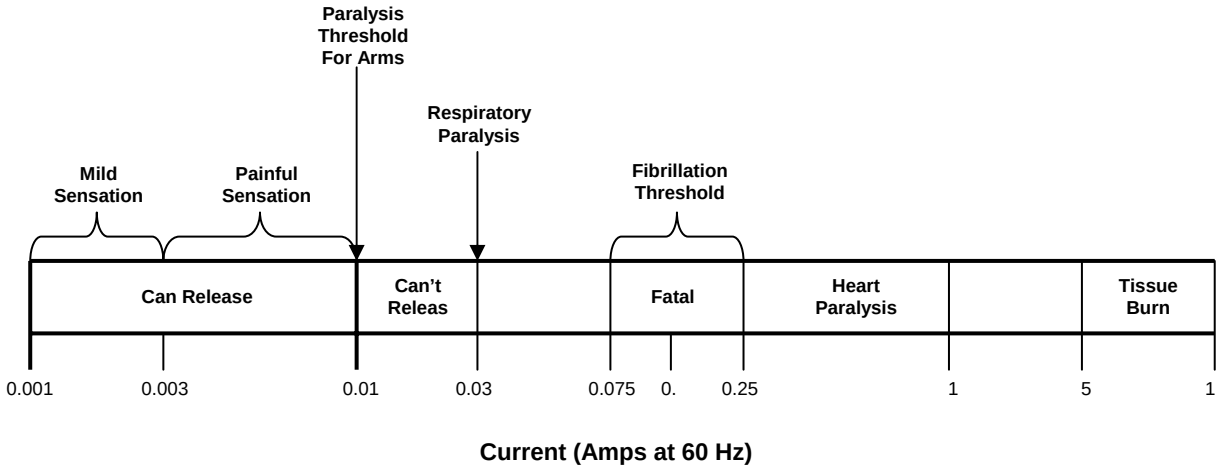

Figure 6.2.1.2 – Effects of Current on Average Human

NOTE: Most GFCI's operate at 0.005 Amps

6.2.1.3 Note that as shock current values are increased they are statistically more dangerous from burn-type damage than heart failure. This is most likely because of the shorter exposure times. When very high voltages (above 2300 V) are involved, burns may not be severe as the victim initiates an arc that retracts (by reflex) the victim's attempted grasp. In summary, humans

are affected in major proportion by the duration, as well as the level of shock. When contact is made in such a manner as to retract the contracting part (such as a light finger touch when the strong muscular contractions of the arm pull the fingers away) the shock is much less dangerous than one of the same current level incurred by "freezing" to the contact with a full hand grasp.

6.2.2 Body Current Levels at 120 Volts AC

6.2.2.1 Typical body current paths are listed in the table below.

Path	Current
Dry Skin	Less than 1 mA
Wet Skin	110 mA
Hand to Foot	220 mA
Ear to Ear	1.1 A

TABLE 130.7(C)(9)(A) *Hazard/Risk Category Classifications*

Task (Assumes Equipment Is Energized, and Work Is Done Within the Flash Protection Boundary	Hazard/Risk Category	V-Rated Gloves	V-Rated Tools
Panelboards Rated 240V and Below-Notes 1 and 3			
Circuit breaker (CB) or fused switch operation with covers on	0	N	N
CB or fused switch operation with covers off	0	N	N
Work on energized parts, including voltage testing	1	Y	Y
Remove/install CBs or fused switches	1	Y	Y
Remove/install bolted covers (to expose bare, energized parts)	1	N	N
Opening hinged covers (to exposed bare, energized parts)	0	N	N
Panelboards or Switchboards Rated >240V and up to 600V (with molded case or insulated case circuit breakers)-Notes 1 and 3			
CB or fused switch operation with covers on	0	N	N
CB or fused switch operation with covers off	1	N	N
Work on energized parts, including voltage testing	2*	Y	Y
600V Class Motor Control Center (MCCs)-Notes 2 (except as indicated) and 3			
CB or fused switch or starter operation with enclosure doors closed	0	N	N
Reading a panel meter while operating a meter switch	0	N	N
CB or fused switch or starter operation with enclosure doors open	1	N	N
Work on energized parts, including voltage testing	2*	Y	Y
Work on control circuits with energized parts 120V or below, exposed	0	Y	Y
Work on control circuits with energized parts >120V, exposed	2*	Y	Y
Insertion or removal of individual starter “buckets” from MCC-Note 4	3	Y	N
Application of safety grounds, after voltage test	2*	Y	N
Removal of bolted covers (to expose bare, energized parts)-Note 4	2*	N	N
Opening hinged covers (to expose bare, energized parts)	1	N	N
600V Class Switchgear (with power circuit breakers or fused switches-Notes 5 and 6			
CB or fused switch operation with enclosure doors closed	0	N	N
Reading a panel meter while operating a meter switch	0	N	N
CB or fused switch operation with enclosure doors open	1	N	N
Work on energized parts, including voltage testing	2*	Y	Y
Work on control circuits with energized parts 120V or below, exposed	0	Y	Y
Work on control circuits with energized parts >120V exposed	2*	Y	Y
Insertion or removal (racking) of CBs from cubicles, doors open	3	N	N
Insertion or removal (racking) of CBs from cubicles, doors closed	2	N	N
Application of safety grounds, after voltage test	2*	Y	N
Removal of bolted covers (to expose bare, energized parts)	3	N	N
Opening hinged covers (to expose, bare, energized parts)	2	Y	N
Other 600V Class (277V through 600V, nominal) Equipment-Notes 2 (except as indicated) and 3			
Lighting or small power transformers (600V, maximum)	-	-	-
Removal of bolted covers (to expose bare, energized parts)	2*	N	N
Opening hinged covers (to expose bare, energized parts)	1	N	N
Work on energized parts, including voltage testing	2*	Y	Y
Application of safety grounds, after voltage test	2*	Y	N
Revenue meters (kW-hour, at primary voltage and current)	-	-	-
Insertion or removal	2*	Y	N
Cable trough or tray cover removal or installation	1	N	N
Miscellaneous equipment cover removal or installation	1	N	N
Work on energized parts, including voltage testing	2*	Y	Y
Application of safety grounds, after voltage test	2*	Y	N

Task (Assumes Equipment Is Energized, and Work Is Done Within the Flash Protection Boundary	Hazard/Risk Category	V-Rated Gloves	V-Rated Tools
NEMA E2 (fused contactor) Motor Starters, 2.3kV Through 7.2kV			
Contactor operation with enclosure doors closed	0	N	N
Reading a panel meter while operating a meter switch	0	N	N
Contactor operation with enclosure doors open	2*	N	N
Work on energized parts, including voltage testing	3	Y	Y
Work on control circuits with energized parts 120V or below, exposed	0	Y	Y
Work on control circuits with energized parts >120V, exposed	3	Y	Y
Insertion or removal (racking) of starters from cubicles, doors open	3	N	N
Insertion or removal (racking) of starters from cubicles, doors closed	2	N	N
Application of safety grounds, after voltage test	3	Y	N
Remove of bolted covers (to expose bare, energized parts)	4	N	N
Opening hinged covers (to exposed bare, energized parts)	3	N	N
Metal Clad Switchgear, 1kV and Above			
CB or fused switch operation with enclosure doors closed	2	N	N
Reading a panel meter while operating a meter switch	0	N	N
CB or fused switch operation with enclosure doors open	4	N	N
Work on energized parts, including voltage testing	4	Y	Y
Work on control circuits with energized parts 120V or below, exposed	2	Y	Y
Work on control circuits with energized parts >120V exposed	4	Y	Y
Insertion or removal (racking) of CBs from cubicles, doors open	4	N	N
Insertion or removal (racking) of CBs from cubicles, doors closed	2	N	N
Application of safety grounds, after voltage test	4	Y	N
Removal of bolted covers (to expose bare, energized parts)	4	N	N
Opening hinged covers (to expose bare, energized parts)	3	N	N
Opening voltage transformer or control power transformer compartments	4	N	N
Other Equipment 1kV and Above			
Metal clad load interrupter switches, fused or unfused	-	-	-
Switch operation, doors closed	2	N	N
Work on energized parts, including voltage testing	4	Y	Y
Removal of bolted covers (to expose bare, energized parts)	4	N	N
Opening hinged covers (to expose bare, energized parts)	3	N	N
Outdoor disconnect switch operation (hookstick operated)	3	Y	Y
Outdoor disconnect switch operation (gang-operated, from grade)	2	N	N
Insulated cable examination, in manhole or other confined space	4	Y	N
Insulated cable examination, in open area	2	Y	N

Note: V-Rated Gloves are gloves rated and tested for the maximum line-to-line voltage upon which work will be done.

V-Rated Tools are tools rated and tested for the maximum line-to-line voltage upon which work will be done.

2* means that a double-layer switching hood and hearing protection are required for this task in addition to the other Hazard/Risk Category 2 requirements of Table 130.7(C)(10).

Y=yes (required)

N=no (not required)

Notes:

1. Maximum of 25kA short-circuit current available, 0.03 second (2 cycle) fault clearing time.
2. Maximum of 65kA short-circuit current available, 0.03 second (2 cycle) fault clearing time.
3. For <10kA short-circuit current available, the hazard/risk category required may be reduced by one number.
4. Maximum of 42kA short-circuit current available, 0.33 second (20 cycle) fault clearing time.
5. Maximum of 35kA short-circuit current available, up to 0.5 second (30 cycle) fault clearing time.
6. For <25kA short-circuit current available, the hazard/risk category required may be reduced by one number.

TABLE 130.7(C)(10) *Protective Clothing and Personal Protective Equipment (PPE) Matrix*

Protective Clothing and Equipment	Protective Systems for Hazard/Risk Category					
Hazard/Risk Category Number	**-1 (Note 3)**	**0**	**1**	**2**	**3**	**4**
Non-melting (according to ASTM F 1506-00) or Untreated Natural Fiber						
a. T-shirt (short-sleeve)	X			X	X	X
b. Shirt (long-sleeve)		X				
c. Pants (long)	X	X	X (Note 4)	X (Note 6)	X	X
FR Clothing (Note 1)						
a. Long-sleeve shirt			X	X	X (Note 9)	X
b. Pants			X (Note 4)	X (Note 6)	X (Note 9)	X
c. Coverall			(Note 5)	(Note 7)	X (Note 9)	(Note 5)
Jacket, parka, or rainwear			AN	AN	AN	AN
FR Protective Equipment						
a. Flash suit jacket (multilayer)						X
b. Flash suit pants (multilayer)						X
c. Head protection		-	-	-	-	-
1. Hard hat			X	X	X	X
2. FR hard hat liner					AR	AR
d. Eye protection		-	-	-	-	-
1. Safety glasses	X	X	X	AL	AL	AL
2. Safety goggles				AL	AL	AL
e. Face and head area protection		-	-	-	-	-
1. Arc-rated face shield, or flash suit hood				X (Note 8)		
2. Flash suit hood					X	X
3. Hearing protection (ear canal inserts)				X (Note 8)	X	X
f. Hand Protection			-	-	-	-
Leather gloves (Note 2)			AN	X	X	X
g. Foot Protection						
Leather work shoes			AN	X	X	X

AN=As Needed AR=As Required

AL=Select one in group X=Minimum required

Notes:

1. See Table 130.7(C)(11). Arc rating for a garment is expressed in cal/cm^2.
2. If voltage-rated gloves are required, the leather protectors worn external to the rubber gloves satisfy this requirement.
3. Hazard/Risk Category Number "-1" is only defined if determined by Notes 3 or 6 of Table 130.7(C)(9)(A).
4. Regular weight (minimum 12 oz/yd^2 fabric weight), untreated, denim cotton blue jeans are acceptable in lieu of FR pants. The FR pants used for Hazard/Risk Category 1 shall have a minimum arc rating of 4.
5. Alternate is to use FR coveralls (minimum arc rating of 4) instead of FR shirt and FR pants.
6. If the FR pants have a minimum arc rating of 8, long pants of non-melting or untreated natural fiber are not required beneath the FR pants.
7. Alternate is to use FR coveralls (minimum arc rating of 4) over non-melting or untreated natural fiber pants and T-shirt.
8. A faceshield with a minimum arc rating of 8, with wrap-around guarding to protect not only the face, but also the forehead, ears, and neck (or alternatively, a flash suit hood), is required.
9. Alternate is to use two sets of FR coveralls (the inner with a minimum arc rating of 4 and outer coverall with a minimum arc rating of 5) over non-melting or untreated natural fiber clothing, instead of FR coveralls over FR shirt and FR pants over non-melting or untreated natural fiber clothing.

TABLE 130.7(C)(11) *Protective Clothing Characteristics*

Hazard/Risk Category	Typical Protective Clothing Systems: Clothing Description (Typical number of clothing layers is given in parentheses)	Required Minimum Arc Rating of PPE [J/cm^2 (cal/cm^2)]
0	Non-melting, flammable materials (ie. Untreated cotton, wool, rayon, or silk, or blends of these materials) with a fabric weight of at least 4.5 oz/yd^2 (1)	N/A
1	FR shirt and FR pants or FR coverall (1)	16.74 (4)
2	Cotton underwear-conventional short sleeve and brief/shorts, plus FR shirt and FR pants (1 or 2)	33.47 (8)
3	Cotton underwear plus FR shirt and FR pants plus FR coverall, or cotton underwear plus two FR coveralls (2 or 3)	104.6 (25)
4	Cotton underwear plus FR shirt and FR pants plus multilayer flash suit (3 or more)	167.36 (40)

Note: Arc rating is defined in Article 100 and can be either ATPV or E_{BT}. ATPV is defined in ASTM F 1959-99 as the incident energy on a fabric or material that results in sufficient heat transfer through the fabric or material to cause the onset of a second-degree burn based on the Stoll curve. E_{BT} is defined in ASTM F 1959-99 as the average of the five highest incident energy exposure values below the Stoll curve where the specimens do not exhibit break open. E_{BT} is reported when ATPV cannot be measured due to FR fabric break open.